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(54) A digital radio transmission system

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Specification

1. Name of the invention
   A digital radio transmission system

2. Scope of claims of patent

In connection with a digital radio transmission system wherein: composite data signals are obtained by inserting additional bits including frame synchronization bits to main data signals at the transmission end of a line switching section; these composite data are transmitted in parallel to currently used lines as well as to a reserve line on stand-by as needed; [signals on] the above-stated currently used lines and the above-stated reserve line are relayed at multiple interim relay stations; the above-stated frame synchronization bits are detected on the reception end of the above-state switching section from each of a pair of the above-stated composite data transmitted in parallel by the above-stated currently used lines and the above-stated reserve line; a synchronous switching method whereby the above-stated pair of the above-stated composite data signals are synchronized with each other using timing[s] of these frame synchronization bits so that lines can be switched without code errors is used; and the first multiple-phase modulation method is used on the above-stated currently used lines and the above-stated reserve line, a digital radio transmission system that is characterized by the fact that at least in one of the sections sandwiched by the above-stated interim relay stations: only the above-stated currently used line[s] is [or are] configured in such a way either that a number of modulation phases or code transmission speed is 1/m (m is an integer which is two or more) respectively of the number of modulation phases and code transmission speed of the above-stated first modulation method, or that using an *m* number of carrier waves, transmission of each carrier wave can be performed at 1/m of code transmission speed.

3. Detailed description of the invention

(Field of [its] industrial use)

The present invention relates to a digital radio transmission method, in particular, a digital radio transmission method that uses a synchronous switching method as its line switching method and a multiple-value modulation method as its modulation method.

(Conventional technology)

It is customary that a radio communication system should have reserve transmission line[s] in preparation for line disconnection due to such things as fading.

When one of currently used lines is to be switched to a reserve line, first, this currently used line is connected in parallel to the reserve line at the transmission end, and two signals transmitted in parallel by this currently used line and reserve line are switched on the receiving end.

There is a propagation delay difference between the currently used and reserve lines, and in addition, since this propagation delay difference fluctuates due to such things as fading, if data signals are transmitted, timings of two [groups of] data signals transmitted in parallel do not necessarily coincide with each other on the receiving end. If a timing gap becomes greater than 1 clock synchronous [cycle], when switching takes place at the receiving end, code errors occur.

In order to avoid these code errors, a synchronous switching method is used in a digital radio communication system.

In a synchronous switching method, a frame synchronization bit [or bits] is [or are] inserted into data signals to be transmitted on the transmission end. Ordinarily, test patterns for monitoring line quality are transmitted on a reserve line while on stand-by, and a frame synchronization bit [or bits] is [or are] inserted into this [or these] test pattern [or patterns] as well. A frame synchronization bit [or bits] is [or are] inserted independently in each of currently used lines and reserve lines, and is asynchronous with each other. Ordinarily, on the transmission end, data signals into which frame synchronous bit [or bits] is [or are] inserted are connected in parallel to currently used lines and reserve lines; and on the reception end, the two data signals transmitted in parallel are synchronized using a timing of a frame synchronous bit [or bits], and [thus] lines are switched without any code error. For this reason, a frame synchronous bit [or bits] in signals transmitted on the reserve line[s] is changed by the parallel connection on the transmission end from a frame synchronous bit [or bits] in test patterns to a frame synchronous bit [or bits] in data signals in the currently used lines; and at this time, on the reception end of the reserve line[s], it takes time to reestablish a frame synchronization relative to the changed frame synchronous bit [or bits], interrupting the line switching operation in the mean time.

Incidentally, recently, a multiple-value modulation method has come to be used often as modulation method in a digital radio communication system.

Since in a multiple-value modulation method, there is more data per code and code transmission speed becomes slower, and radio frequency width for its exclusive use can be small, radio frequencies can be used more effectively, but deterioration of code transmission quality due to distortion in radio propagation paths and in the equipment increases rapidly as modulation quantity increases.

Accordingly, if there is one section in which propagation conditions are particularly poor among multiple sections between interim relay stations in one switching section on a line, a measure is taken only in this section to prevent particularly great deterioration of the code transmission quality either of making a modulation value smaller or of making code transmission speed slower by using multiple carrier waves per line. In such a case, if either of the measures is taken, it will be necessary to convert data rows at relay stations on both sides of this section.

For example, if a 4-phase Phase Shift Keying Modulation (hereinafter referred to as 4PSK) method is used in a section with poor propagation conditions and a 16-valuse Quadrature Amplitude Modulation (hereinafter referred to as 16QAM) method is used in the other sections, then, four rows of data obtained by demodulating 16QAM signals are converted to two rows at the interim relay stations on the transmission side in this section, and 4PSK signals are obtained from these two rows of data. At interim relay stations on the reception side, the two rows of data obtained by demodulating the 4PSK signals are converted to four rows, and 16QAM signals are obtained from these four rows of data. Or if only a code transmission speed is changed to ½ without changing the 16QAM Method, at transmission-side interim stations, two sets of four rows of data each are obtained by converting four rows of data to eight rows, and one 16QAM signal per set or two such signals in total are obtained respectively from each set of the data rows. At the receiving-side interim relay stations, two sets of four rows of data obtained by demodulating each of the two 16QAM signals are converted by eight-row · four-row conversion into four rows, and 16QAM signals are obtained from these four data rows.

In the former method at the receiving-side interim relay stations and in the latter method at the transmission-side interim relay stations, one row of data is converted to two rows; and when one data row is frequency-divided by *m* into an *m* rows of data in such a manner, unless there are some phase standards for frequency division, an *m* rows of data is not determined univocally due to a phase characteristic of uncertainty of frequency division. In other words, a determination as to in which row among the *m* rows of data a certain data bit is placed is not univocally made. If this phase uncertainty exists in row conversions, and even if either of the above-stated methods is used,

orders in which four rows are placed respectively at the transmission-side interim relay stations and reception-side interim relay stations do not necessarily coincide with each other, accordingly, a problem arises in that orders of [data] rows in a switching section of a line are not the same between the transmission side and receiving side.

It is necessary to have a phase standard for frequency division in order to avoid this problem, and a frame synchronous bit inserted for synchronous switching is used as this phase standard. For this reason, it is necessary to have frame synchronization established, at a reception-side interim relay station if the above-stated former method is used, and at a transmission-side interim relay station if the latter method is used.

Conventionally, if a method was used such as using a small number of modulation phases or multiple carrier waves per line in a certain specific section out of sections between interim relay stations as described above, the same method was used not only in currently used lines but also in reserve lines.

As already explained with respect to synchronous switching, if the transmission end is connected in parallel when lines are switched, a frame synchronous bit changes in reserve lines, so it takes time to reestablish frame synchronization in a reserve line where an interim relay station is performing row conversion between one row and *m* rows, and after this frame synchronization is reestablished and the row conversion is performed correctly, does an operation begin for frame synchronization to be reestablished at a reception end of the reserve line.

(A Problem being solved by the invention)

As explained above, a conventional digital radio transmission system using a synchronous switching method as line switching method and multiple phase modulation method as modulation method has a drawback in that it takes a long time to switch lines because: if a certain section out of some sections between interim relay stations has particularly poor propagation conditions, in order to reduce deterioration of code transmission quality in this section, such a method is taken as using a smaller number of modulation phases for both currently used and reserve lines in this section and using multiple carrier waves per line; for this reason, it is necessary to perform row conversion between one row and *m* rows of data at interim relay stations at either the transmission or reception side, and it is [also] necessary to have frame synchronization established to perform the row conversion; and if this frame synchronization on a reserve line goes off during line switching, until it is reestablished, a frame synchronization operation at the receiving side on the reserve line does not begin.

The purpose of the present invention is: while still using a synchronous switching method and multiple-phase modulation method, to provide a digital radio transmission system which reduces deterioration of code transmission quality in sections where propagation conditions are particularly poor, and in addition, with respect to which it takes a short time to switch lines.

(A Means to Solve the Problem)

The digital ratio transmission system in accordance with the present invention is: in connection with a digital radio transmission system wherein: composite data signals are obtained by inserting additional bits including frame synchronization bits to main data signals at the transmission end of a line switching section; these composite data are transmitted in parallel to currently used lines as well as to a reserve line on stand-by as needed; [signals on] the above-stated currently used lines and the above-stated reserve line are relayed at multiple interim relay stations; the above-stated frame synchronization bits are detected on the reception end of the above-state switching section from each of a pair of the above-stated composite data transmitted in parallel by the above-stated currently used lines and the above-stated reserve line; a synchronous switching method whereby the above-stated pair of the above-stated composite data signals are synchronized with each other using timing[s] of these frame synchronization bits so that lines can be switched without code errors is used; and the first multiple-phase modulation method is used on the above-stated currently used lines and the above-stated reserve line, a digital radio transmission system that is configured such that: at least in one of the sections sandwiched by the above-stated interim relay stations: only the above-stated currently used line[s] is [or are] configured in such a way either that a number of modulation phases or code transmission speed is 1/m (m is an integer which is two or more) respectively of the number of modulation phases and code transmission speed of the above-stated first modulation method, or that using an *m* number of carrier waves, transmission of each carrier wave can be performed at 1/m of code transmission speed.

(Embodiments)

Details of the present invention are explained as follows while referring to figures showing embodiment[s].

Figure 1 is a block diagram showing the first embodiment of a digital radio transmission system in accordance with the present invention.

1 is a transmission-end radio terminal station; 2 ~ 4, interim relay stations; [and] 5, a reception-end radio terminal station. It is assumed that a section between interim relay stations 3 and 4 has particularly poor propagation conditions compared with the other sections between all these stations.

The transmission-end radio terminal station 1 is configured to be equipped with a transmission-end line switch 100 and transmitters 110 ~ 112. The transmission-end line switch 100

structures a frame by inserting to inputted data signals, D_1 and D_2, additional bits such as frame synchronous bits and data bits for digital service channels respectively, and further arranges them into four rows of data respectively and outputs them to the transmitters 111 and 112. Also, the transmission-end line switch 100 generates test patterns, into which frame synchronous bits, etc., are similarly inserted and which are turned into frames; and while a reserve line is on stand-by, it outputs these test patterns to the transmitter 110 and when the lines are switched, it also outputs in parallel to the transmitter 110 four rows of data that are transmitted to the transmitter 111 or transmitter 112. The transmitter 110 is a transmitting device for the reserve line, the transmitter 111, a transmitting device to transmit data signal D_1 on the currently used lines; and the transmitter 112, a transmitting device to transmit data signal D_2 on the currently used lines. Each of the transmitters 110 ~ 112 transmits modulated waves, W_{10} ~ W_{12} that are 16QAM waves that were modulated respectively with each of four rows of inputted data.

The interim relay station 2 is configured to be equipped with receivers 220 ~ 222, each of which receives modulated waves, W_{10} ~ W_{12} and outputs four rows of data,

and with transmitters 210 ~ 212 that transmit modulated waves, W_{10} ~ W_{12} that are 16QAM waves that were modulated respectively with each of four rows of data outputted by the receivers 220 ~ 222.

Interim Relay Station 3 is configured to be equipped with receivers 320 ~ 322 that receive modulated waves W_{20} ~ W_{22} and transmitters 310 ~ 312, each of which outputs four rows of data. The transmitter 310 outputs modulated wave W_{30} which is 16QAM wave modulated with four rows of data outputted by the receiver 320. The transmitters 311 and 312 convert respectively four rows of data outputted by the receivers 321 and 322 into respectively two rows of data rows and output modulated waves W_{31} and W_{32} that are 4PSK waves that were modulated respectively with these two rows of data rows.

Interim Relay Station 4 is configured to be equipped with receivers 420 ~ 422 and transmitters 410 ~ 412. The receiver 420 receives the modulated wave W_{30} and outputs four rows of data rows. The receivers 421 and 422 receive modulated waves W_{31} and W_{32} and obtain respectively two rows of data rows; they generate frame pulses by detecting frame synchronous bits inserted into these two rows of data rows;

and using these frame pulses as frequency division phase standards, they convert these two rows of data rows into four rows of data rows respectively and output them. Making row conversion between two rows and four rows using the frequency division phase standard makes it possible to match the order of four rows of data rows outputted respectively by the receivers 421 and 422 with the order of four rows of data rows outputted respectively by the receivers 321 and 322 at the interim relay station 3. The transmitters 410 ~ 412 output modulated waves W_{40} ~ W_{42} that are 16QAM waves which were modulated with four rows of data rows outputted respectively by the receivers 420 ~ 422.

The reception-end radio terminal station 5 is configured to be equipped with receivers 520 ~ 522 that receive the modulated waves W_{40} ~ W_{42} and respectively output four rows of data rows and a reception-end line switch 500. If a reserve line is on stand-by, the reception-end line switch 500 converts four rows of data rows outputted respectively by the receivers 521 and 522, reversing the conversion performed at the transmission-end line switch 100, to generate data signals D_1 and D_2 and outputs them; and it [the receiving-end line switch 500] similarly converts four rows of data rows outputted by the receiver 520 into test patterns,

and monitors by these test patterns code transmission quality of the reserve line. Also, if lines are switched, for example, if a currently used line that transmits data signal D_1 is switched to the reserve line, after completion of the transmission-end parallel connection at the transmission-end radio terminal station 1, the reception-end line switch 500 switches synchronization of four rows of data rows respectively outputted by the receivers 520 and 521, and converts data row[s] outputted by the receiver 520 (the data row[s] outputted via the reserve line) into the data signal D_1 and outputs it. Switching of the synchronization here is accomplished by: detecting frame synchronous bits inserted into four rows of data rows respectively outputted by the receivers 520 and 521 and generating frame pulses [thus]; and synchronizing two sets of four rows of data rows each by using the timing of these frame pulses. The data rows outputted by the receiver 520 by the transmission-end parallel connection are changed from data rows generated by the test patterns to data rows generated by the data signal D_1, and the frame synchronous bit in the data row is also changed thereby. Because of this, as already stated, it takes time to reestablish frame synchronization, and in the mean time, a switching operation is interrupted.

As explained above, the embodiment shown in Figure 1 reduces particularly great deterioration of code transmission characteristics in the section between the interim relay stations 3 and 4 wherein the propagation conditions are particularly worse than in the other sections by using a 4PSK method only in the currently used line[s] and a 16QAM method in the reserve line in this section, as well as in the currently used lines and reserve lines in the other sections. In this section, too, a 16QAM is still used in the reserve line, but since odds of both the currently used lines and reserve line getting deep fading are sufficiently small, it is possible by the reserve line using a 16QAM to remedy (a line getting disconnected due to) deterioration of code transmission quality of the currently used lines using a 4PSK method. In the reserve lines, transmission is carried out with a 16QAM method in each of the sections, and there is no conversion of numbers of data rows at the interim relay stations. Accordingly, since frame synchronization is not required for relay at the interim relay stations, it is never the case that it takes time to reestablish frame synchronization at line switching at the interim relay stations and that it takes longer to switch the lines.

Figure 2 is a block diagram showing the second embodiment of a digital radio transmission system in accordance with the present invention.

The embodiment shown in Figure 2 is an embodiment in which the section between the interim relay stations 3 and 4 where propagation conditions are particularly poor in the embodiment shown in Figure 1 is replaced by a section between the interim relay stations 6 and 7. The interim relay station 6 is configured in such a manner that the transmitters 311 and 312 of the interim relay station 3 are replaced by transmitters 611 and 612. The interim relay station 7 is configured in such a manner that the receivers 421 and 422 of the interim relay station 4 are replaced by receivers 721 and 722.

The transmitter 611 generates frame pulses by detecting frame synchronous bits inserted into four rows of data rows outputted by the receiver 321, obtains two sets of four rows of data rows each by converting four rows of data rows into eight rows using the frame pulses as frequency division phase standard, and outputs modulated waves, W_{61} and W_{62}, 16QAM waves that were modulated respectively with the four rows of data rows in each of the two sets. The transmitter 612 similarly inputs four rows of data rows outputted by the receiver 322, and outputs modulated waves, W_{63} and W_{64}, each 16QAM wave.

The receiver 721 receives the modulated waves, W_{61} and W_{62}, and obtains two sets of data rows that are each four rows of data rows; and it converts the two sets of four rows of data rows each into one set of four rows of data rows and outputs them. The receiver 722 similarly receives the modulated waves, W_{63} and W_{64}, and outputs four rows of data rows. Performing row conversion between four rows and eight rows by using a frequency division phase standard makes it possible to match an order of four rows of data rows respectively outputted by the receivers 321 and 322 at the interim relay station 6 with an order of four rows of data rows respectively outputted by the receivers 721 and 722 at the interim relay station 7. Operations of all devices that were not described in the above are the same as those in the embodiment shown in Figure 1.

As explained above, by using two carrier waves per line only in the currently used lines in the section between the interim relay stations 6 and 7, of which propagation conditions are particularly worse than those of the other sections and by making the code transmission speed ½ of the [transmission speed] on the reserve line in this section and on the reserve line and currently used lines in the other sections, the embodiment shown in Figure 2 reduces particularly great deterioration of code transmission characteristics in the [above-stated] section. The fact that an effect of the remedy of the currently used lines is sufficient even without making slower the code transmission speed on the reserve line in this section and the fact that a line switching time is shorter are just the same as in the case of the embodiment shown in Figure 1.

As [described] above, an embodiment in accordance with the present invention, in which currently used lines are comprised of two lines and one reserve line and a 16 QAM Method is used in the currently used lines and reserve line, was explained above. The present invention, however, is applicable no matter how many currently used lines or reserve lines there may be, and is applicable to a modulation method, as long as the modulation method is multiple-phase modulation method, no matter how many the number of phases may be.

(Effect of Invention)

As explained in detail above, a digital radio transmission system in accordance with the present invention, by using a synchronous switching method as line switching method, by using a multiple-phase modulation method as modulation method, and by reducing a number of phases of the modulation method in a section out of sections between interim relay stations in which propagation conditions are particularly poor or by using multiple carrier waves per line and [thus]

reducing a code transmission speed per carrier wave, has an effect of reducing a possibility of particularly great deterioration of the code transmission characteristics in this section; and has an effect of having a shorter line switching time, because the modulation method is not changed, nor is the code transmission speed per carrier wave changed even in this section on the reserve line, and because it is not necessary to perform row conversions of data rows transmitted on the reserve line at interim relay stations, nor is it necessary to perform frame synchronization on the reserve line at the interim relay stations for the purpose of relaying.

4. Simple Explanation of Figures

Figure 1 and Figure 2 are block diagrams showing respectively the first embodiment and second embodiment of a digital radio transmission system in accordance with the present invention.

1 ······ a transmission-end radio terminal station; 2 ~ 4, 6, 7 ······ interim relay stations; 5 ······ a reception-end radio terminal station; 100 ······ a transmission-end line switch; 110 ~ 112, 210 ~ 212, 310 ~ 312, 410 ~ 412, 611 ~ 612 ······ transmitters; 220 ~ 222, 320 ~ 322, 420 ~ 422, 520 ~ 522, 721, 722 ······ receivers; 500 ······ a reception-end line switch

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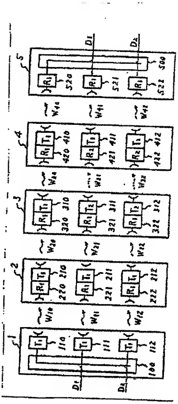
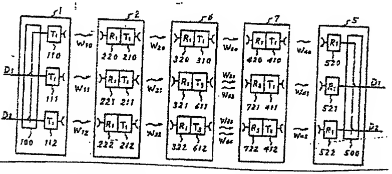


1: Transmission-end radio terminal station
2 ~ 4: Interim relay stations
5: Reception-end radio terminal station
100: Transmission-end line switch

110 ~ 112, 210 ~ 212, 310 ~ 312, 410 ~ 412: Transmitters
220 ~ 222, 320 ~ 322, 420 ~ 422, 520 ~ 522: Receivers
500: Reception-end line switch D_1 and D_2: data signals
W_{10} ~ W_{12}, W_{20} ~ W_{22}, W_{30} ~ W_{32}, W_{40} ~ W_{42}: Modulated waves

Figure 1



1: Transmission-end radio terminal station

2 ~ 4: Interim relay stations

5: Reception-end radio terminal station
100: Transmission-end line switch

110 ~ 112, 210 ~ 212, 310, 410 ~ 412, 611, 612: Transmitters
220 ~ 222, 320 ~ 322, 420, 520 ~ 522, 721, 722: Receivers
500: Reception-end line switch D_1 and D_2: data signals
W_{10} ~ W_{12}, W_{20} ~ W_{22}, W_{30}, W_{40} ~ W_{42}, W_{61} ~ W_{64}: Modulated waves

Figure 2